

MANAGING SCIENCE OPERATIONS DURING PLANETARY SURFACE OPERATIONS AT LONG LIGHT DELAY-TIME TARGETS: THE 2011 DESERT RATS TEST. D. B. Eppler¹ and the Desert RATS Science Operations Team, ¹Exploration Sciences Office, Mail Code KX, NASA-Johnson Space Center, 2101 NASA Parkway, Houston, TX, 77058, dean.b.eppler@nasa.gov

Introduction: Desert Research and Technology Studies (Desert RATS) is a multi-year series of hardware and operations tests carried out annually in the high desert of Arizona in the San Francisco Volcanic Field. Conducted since 1997, these activities are designed to exercise planetary surface hardware and operations in conditions where multi-day tests are achievable. Such activities not only test vehicle subsystems through extended rough-terrain driving, they also stress communications and operations systems and allow testing of science operations approaches to advance human and robotic surface capabilities. Desert RATS is a venue where new ideas can be tested, both individually and as part of an operation with multiple elements. By conducting operations over multiple yearly cycles, ideas that “make the cut” can be iterated and tested during follow-on years. This ultimately gives both the hardware and the personnel experience in the kind of multi-element integrated operations that will be necessary in future human planetary exploration.

Desert RATS 2011 Science Operations Test simulated the management of crewed science operations at targets that were beyond the light delay time experienced during Low-Earth Orbit (LEO) and lunar surface missions, such as a mission to a Near-Earth Object (NEO) or the martian surface. Operations at targets at these distances are likely to be the norm as humans move out of the Earth-Moon system. Operating at these distances places significant challenges on mission operations, as the imposed light-delay time makes normal, two-way conversations extremely inefficient. Consequently, the operations approach for space missions that has been exercised during the first half-century of human space operations is no longer viable, and new approaches must be devised.

Conduct of the actual test took place between 30 August and 9 September 2011. A total of 8 crewmembers participated in a variety of exploration science scenarios that tested operations around a NEO using several small-pressurized exploration vehicles and a single habitat. Communications between the “ground” and the crew in the field used a 50-second one-way light-time delay (110 s total delay), while communications between crewmembers in the exploration vehicles and the habitat were instantaneous.

The actual conditions of the simulation, of necessity, were unable to mimic the complexity of proximity and EVA operations in the vicinity of a heterogeneous small body such as a NEO. However, the introduced communications constraints did allow the test team to understand the effects of long light-delay times on operational

approaches. Bleacher, et. al. [1] discuss in more detail the field operations and lessons learned by the crewmembers. This report will discuss the operational approaches and lessons learned by the Science Operations Team that operated out of the Mission Control Facility at the Johnson Space Center.

Science Operations Management Approach: In previous Desert RATS operations, the science support room has operated from the Black Point Base Camp area near Flagstaff, AZ. This approach was driven by a combination of communications infrastructure constraints and general desire for the operations team to be physically close to the mission infrastructure to allow real-time, face-to-face contact between different mission teams. This permitted the overall mission team to manage both nominal and contingency operations more efficiently by allowing team members to meet and resolve issues face-to-face. However, the maturity of the Desert RATS team and a desire to test operations from a distant venue led to the decision to conduct the 2011 operation from the Mission Control Facility at Johnson Space Center. In addition, as planning was proceeding it was decided to add the European Space Agency as one of the science operations control nodes for a portion of the test.

Significant two-way delay times in communications are a standard part of operating planetary surface exploration operations, and the Mars Exploration Program has demonstrated increasing proficiency in managing these operations over the last 20 years. However, all previous human space operations have been managed with one-way delay times of ≤ 5 seconds. In order to stress the operational system, the delay time was introduced to simulate operations at a NEO. Extensive dry run testing at Johnson Space Center in the spring and summer of 2011 showed that two way conversations were simply untenable – in particular, the 50-second delay was sufficiently long that, in the normal workload of running a surface operation, it was possible to forget that a conversation had been initiated by the time a response had been received. Consequently, it was clear early on that other methods of communication would be necessary. Also, the present Deep Space Network places limitations on the amount of data that can be returned in a given time period. Improvements, such as the use of laser-based communications devices, could increase the data return, but such upgrades are not yet included in mission planning. As a result, it was decided to test the effect on operations using bandwidths that simulated present DSN conditions and a future, upgraded system capability.

Dry run test results showed that collection, management and interpretation of science data would be a

“one-shot” deal; that is, the communications delay would not allow science team members to request clarification or repetition of science observations. Consequently, the decision was made to expand the number of science team members collecting written geologic context and sample data, and to separate the transcription of that data from the collection of visual data through “frame grabbing”. In addition, it was recognized that interaction with the crew could be more efficient through the use of one-way text messaging rather than verbal communication.

By varying the conditions of individual test runs between the number of exploration vehicles in the field, the number of crewmembers in each vehicle, the number of crewmembers on EVA and the crewmembers who interacted with the operations team, the science team was able to evaluate which configuration provided the most efficient operations. Lastly, communications within the operations control room have traditionally been conducted over voice “loops” within a given specific team, and within the larger control team. This year, the use of text communications and the need for a fast approval cycle for uplinked texts prompted the Data Manager to experiment with chat rooms as a method of communication within the control room.

Lessons Learned: (1) The Science Operations Team was able to assess the geology of each during crew EVAs in order to solve critical, original geologic problems in real time. This was accomplished through a combination of good observations by the crew, good communication of those observations, and the scientific skills of the Science Team in Houston. (2) Conducting tactical science operations with a communications delay proved far less onerous than was imagined prior to the beginning of the test, leading to a smoother operations tempo than expected. In particular, the Science Team members responsible for collecting data were able to acquire and process the data that was coming down without few issues relative to missed data or problems associated with the inability to interact with the crew in real time. (3) Integrating the Science Operations Team in the same room as the Mission Operations Team was very successful, resulting in good communications and decision making between the Science Operations Team and their Mission Operations counterparts. In particular, having the Science Lead seated next to the Flight Director and the CAPCOMM and SCICOM operating the same console led to good communication for all phases of the operations. (4) The mix of Science Operations Team positions and the number of team members worked well, although there were issues where some operational phases left team members under-utilized, while others phases pushed every team member to operate at their limits. (5) The use of the chat pages for communication within the Science Operations team worked very well. In particular, using chatrooms cut

down on the chatter on the voice loops, and gave the Science PI and the Flight Director a method to quickly review draft text messages prior to uplink by the Science Communicator (SCICOM) and the primary crew contact (CAPCOM) without overloading voice loops. (6) Operations with ESA went smoothly, in spite of limited time and budget that ESA had available to assemble, organize and practice for this mission. (7) During the periods of restricted bandwidth, the flow of science information from the field to the Science Operations team room was adequate to conduct real-time, tactical science operations, but was not sufficient to have run a strategic analysis team as was done during Desert RATS 2010 [2]. (8) Texting works. The ability to text to crewmembers smoothed out science information flow between the Science Team and the crew more efficiently than was anticipated prior to the test, particularly with an IV crewmember in the loop. In particular, interaction with the crew could be accomplished with a combination of texting and voice depending on the time sensitivity of the information. (9) Using a crewmember in a real-time, IVA “Control Room Forward” role appeared to the Science Team to be the most efficient way of conducting science operations with a time-delay. The IVA crewmember operated as an efficient information buffer for the operations flow between the Science Operations Team and the crew on the outcrop, working the text inputs from the Science Operations Team into real time actions for the crew while still maintaining situational awareness of the operations in the field. (10) Data management systems need to be integrated better to link sample and geologic context data within a geographic, and to allow operations teams to link image data without a chance of image ID-tag errors. Image data, in particular, can be difficult to re-find if image numbers are incorrectly copied between competing databases.

The 2011 RATS Science Operations Test was extremely successful, testing new operations approaches to managing science data and crew operations on planetary surfaces under communications and data constraints not experienced during previous human spaceflight operations.

References: [1] J. Bleacher, et. al. (2012), *LPSC XLIII*, Abstract this meeting. [2] Eppler, et. al. (2011) *LPSC XLII Abst. #1831*.